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AUTHOR Doncov, Boris
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ABSTRACT

The only operational Soviet time-sharing systems are incorporated in special-purpose, fixed-application installations, most of which are intended for industrial applications of process control or management information. Despite the peculiar suitability of time-sharing to the Soviet economic system, with its heavy reliance on centralized planning and progress reporting, time-sharing research projects are noteworthy for their lack of progress, their reliance on existing, marginally suitable hardware, and their failure to solve the problem of unreliable data-transmission facilities. The report concludes that it is now propitious to bring into focus the status of existing work on time-sharing and its historical background as a prelude to assessing new work that can be expected to follow the introduction of Ryad and the implementation of projects promised in the current Five-year Plan. (Author)

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Soviet Cybernetics Technology: XII. Time-Sharing in the Soviet Union

Boris Doncov

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PREFACE

This study of the status of research and development projects in computer time-sharing in the Soviet Union was commissioned by Rand's Soviet Cybernetics Technology project, under U.S. Air Force Project Rand, in the summer of 1969 and updated in the spring of 1971. The author is an electrical engineer with a native background in Russian. He was formerly employed as a technical analyst of Soviet scientific literature with the Aerospace Technology Division of the Library of Congress.

The author surveyed all relevant Soviet literature sources available at Rand for the information on which this report is based. His original conclusions, reached in 1969, have since been confirmed by the almost startling lack of progress that has been made in the various Soviet time-sharing projects.

This report establishes the importance of time-sharing for the Soviets and examines why no significant effort has been made to develop the needed systems. These historical aspects are particularly important in light of the recently promulgated Directives of the 25th Congress of the Communist Party and the statement of goals for the 1971-75 Five-year Plan. These documents indicate that, for the first time, major emphasis is to be placed on computer development and the refinement of computational and econometric techniques. Included within this rubric are three important nationwide systems--a state network of computer centers, an automated economic planning and management system, and a unified automated national communications system. Time-sharing systems must be developed in order to properly implement the first two systems, while the third system is a necessary prerequisite for time-sharing systems that include data-transmission facilities. As the details of these proposed systems assume concrete form, it will be important to understand how they interface with Soviet potentials for time-sharing.

Also of particular importance is the impending appearance of the Ryad series of third-generation computers. Patterned after the IBM System/360, these machines should hold the major promise for the development of time-sharing systems in the Soviet Union. The report

considers the existing state of Soviet computer technology, the major computers suitable for time-sharing, and the on-going time-sharing research and development projects. Based on this background and the prospects for the computer field over the next few years, the report establishes the context for future analysis of this important aspect of Soviet computer development.

This report is part of Rand's research in Soviet cybernetics.[†] The series *Soviet Cybernetics Technology* is intended to inform interested computer specialists about Soviet publications, activities, and new developments in computing technology and cybernetics.

[†] A bibliography of Rand publications on Soviet cybernetics and computer technology is appended.

SUMMARY

The only operational Soviet time-sharing systems are incorporated in special-purpose, fixed-application installations, most of which are intended for industrial applications of process control or management information. Despite the peculiar suitability of time-sharing to the Soviet economic system, with its heavy reliance on centralized planning and progress reporting, time-sharing research projects are noteworthy for their lack of progress, their reliance on existing, marginally suitable hardware, and their failure to solve the problem of unreliable data-transmission facilities.

This report appears at a time that may in retrospect be seen as the transition period between the largely unsuccessful, early projects currently identified and the new, promising projects that will be undertaken in the near future as a result of two important events--the appearance within the next year (according to schedules) of the Ryad third-generation computers with their inherent capacity for time-sharing applications; and an announced intention to emphasize the development of computers and computational techniques during the 1971-75 Five-year Plan. The report provides the background for understanding why the Soviets have so far failed to take a significant interest in time-sharing and why the few projects that have been undertaken have not fulfilled their promises.

All time-sharing projects to date have aimed at utilizing such existing computers as the Minsk-22, M-220, and BESM-6. These machines can provide only small-scale time-sharing systems. Other computers currently available on which similarly rudimentary time-sharing could be based include the Ural series (Ural-11, Ural-14, and Ural-16). The most important work to date has been the AIST system at the Novosibirsk Science City; it is several years behind schedule and appears to be the victim of incompatibility between its designer's desires and the available equipment on which it must be based. The potential for time-sharing development at the Computer Center of the USSR Academy of Sciences does not appear to have been exploited. In Kiev, the Institute of Cybernetics has been successful in implementing a special-purpose, fixed-program system with a minimal time-sharing capability for industrial production scheduling.

A general-purpose time-sharing system using a medium-power machine, the M-220, has been reported from Kazan', but there are no indications of its operational use. A form of special-purpose time-sharing is used in the new airline reservations and ticketing system developed for Aeroflot. These few projects exhaust the known activity in the Soviet Union to develop time-sharing capabilities.

The prognosis for the future is not as grim as it would be if one were to examine only the work under way. Much more important are the potential impact the Ryad machines will have and the new Party and government attitude toward computers. The report concludes that it is now propitious to bring into focus the status of existing work on time-sharing and its historical background as a prelude to assessing new work that can be expected to follow the introduction of Ryad and the implementation of projects promised in the current Five-year Plan.

CONTENTS

I. INTRODUCTION

Computer time-sharing can be viewed as a gradual evolutionary development resulting from the way computers were designed and used. The number of users literate in the progressively easier computer languages grew in step with increasing computer capabilities. The traditional relationship between the man with the problem and the computer, involving a programmer as an intermediary, became burdensome, lengthening both user and job queues. Batch-processing, involving fast, expensive, and underused Central Processing Units (CPUs) was no longer economical nor expedient since turnaround time measured in hours seemed unreasonable when actual computations required only minutes of machine time.

It is no accident that time-sharing methods for resolving these discrepancies occurred simultaneously to many people. Using the technology and techniques at hand, it was only necessary to reorganize the hardware and software so that a number of remote users could concurrently interact with the computer, each with the impression that the entire computational power was under his command alone. As a result, many time-sharing installations sprang up almost simultaneously in 1963: at the Massachusetts Institute of Technology (Project MAC); at the System Development Corporation in Santa Monica, California; and at the California Institute of Technology.

The pressures that provided the impetus for the development of time-sharing systems in Western countries were not as prominent in the Soviet Union in 1963. Time-sharing was not justifiable in terms of increased efficiency of computer utilization since Soviet computing of that period was characterized by small-scale hardware (predominant models were in the range of 5000-20,000 opns/sec, with maximum core memory capacities of 8000 words) and inordinately long down-times (most designs relied on vacuum tubes). The unreliability and underdevelopment of input/output (I/O) devices also precluded such a venture. Software development so lagged behind Western achievements that progress could hardly be perceived. The lack of computer maintenance and programming personnel was commensurate with the Soviet software void. Organizational problems associated with computer manufacture and utilization severely limited

the development of new modes of usage, and the problem of standardization was of comparable magnitude.

Thus, whereas time-sharing gained almost immediate acceptance and popularity in the United States, in the Soviet Union conditions were unfavorable for its development. However, in anticipation that Western trends would take hold when transplanted into the Soviet environment, Soviet designers began to incorporate into their computer models such features as program interrupt, external communication channels, and supervisory systems. These features were initially intended for more efficient organization of batch-processing tasks, but they subsequently assumed greater importance in view of the popularity of time-sharing in the United States. Such semiconductorized computer models as the M-220, Minsk-23, Ural-14, Ural-16, and BESM-6 incorporate time-sharing features in varying degrees, although for a variety of reasons they could not be put to immediate use.

One may surmise that Soviet computer designers, being well versed in the latest Western technological innovations, benefit from this technological lag by including "borrowed" ideas and techniques in their designs without having to test these under actual operating conditions. This is due to the enormous--and almost unilateral--flow of technological information from the West. The All-Union Institute for Scientific and Technical Information, employing 24,500 people to monitor and translate significant scientific information, makes Western technical literature available [1]. Personal contacts at scientific conferences are also of great value to the Soviets [2].

Time-sharing places stringent demands on computing installations in terms of CPU speed, main memory capacity, auxiliary storage space, terminal equipment, internal coordinating software, and techniques and procedures for man-machine interaction. Therefore, an analysis of a much greater number of interrelated factors than just the principal computer hardware becomes necessary and a much broader view of the Soviet computing scene must be brought into focus.

This report examines Soviet general-purpose time-sharing systems that provide the capability for writing programs from remote terminals. Systems with fixed application programs, such as found in process

control and business applications, are also treated because they may exert a certain amount of influence on general-purpose time-sharing systems. The paucity of available published material on current Soviet time-sharing activities makes for a certain lack of clarity and definition. This is due to Soviet publication lags and to the sketchy manner in which Soviet technical literature is presented. An attempt is made to include all available pertinent information, but this does not preclude the existence of time-sharing activities that are unknown in the West.

Three factors suggest the possibility of a highly accelerated rate of development of time-sharing systems, especially as compared to previous development programs in other areas of computer technology: (1) the special suitability of time-sharing as an important element in curing some of industry's basic problems; (2) the increasing emphasis placed on all aspects of computer development by the Soviet government; and (3) recent evidence of a Soviet willingness to effect jurisdictional and organizational changes in the apparatus for computer design, development, and manufacture. An analysis of these factors gives a broad view of existing Soviet potential for progress in time-sharing.

II. THE STATE OF SOVIET COMPUTING

In a 1966 report to the 23d Congress of the Communist Party of the Soviet Union, Party Secretary L. I. Brezhnev pointed out that the insufficient growth of computer technology and inadequate computer use were increasing the gap in many fields between theoretical research and production [3]. In the same report, Brezhnev recognized computer technology's potential for generating a real revolution in production, planning, economics, accounting, and even scientific research. That this was--and still is--a latent characteristic (due to organizational and technical problems) was echoed by the Soviet press.

There was a time when the responsibilities of Soviet computer manufacturers ended at the loading platform, with the user left to his own devices in installing, operating, and servicing the machine--if he were lucky enough to obtain and assemble the various peripheral equipment needed. To what extent this situation still exists is not known, but the press continues in 1971 to criticize the lack of support provided computer users by the manufacturers.

Such institutions as the USSR Ministry of Instrument Construction, Means of Automation, and Control Systems, the USSR Ministry of the Radio Industry, the USSR Ministry of the Electrical Engineering Industry, the Central Statistical Administration, and the State Committee on Science and Technology of the Council of Ministers, have created tenacious, artificial jurisdictional boundaries that result in parallel computer technology developments with none of the benefits that might be realized from competition [4]. Diffusion of funds, duplication of effort, and lack of standards in this field cause grave problems both in the development of computer hardware and software and in the compatability of existing systems. These problems hinder large-scale infusion of computers and computer-based techniques into the national economy.

The problem of staffing computer installations is also acute and promises to assume alarming proportions. E. A. Yakubaytis of the Academy of Sciences of the Latvian SSR noted in 1967 that "the planned output of programmers for the year 1970 is approximately 5 to 6 times

less than the number required at present" [5]. Shortages of qualified operating and maintenance personnel contribute to inefficient utilization of computers [6-7]. This is especially true at installations equipped with older computer models, where there is a high turnover in more qualified personnel because, presumably unsatisfied with being used as coders, they search for more challenging employment, such as can be found at Academy computer centers [6]. This results in an imbalance in computer usage between production enterprises and educational and research institutes. At the 1965 meeting of the USSR Academy of Sciences, it was admitted that computers stand idle at many industrial enterprises in Minsk, while those at the Institute of Mathematics of the Belorussian SSR Academy of Sciences are operated around the clock--and are still unable to cope with demand [5]. Another source corroborates reports of idle computers, purchased for the sake of being "in style" and operated only one or two hours a day [8].

There is much discussion in the press about the State Network of Computer Centers, which has the ambitious goal (set in 1966 after Brezhnev's speech) of providing all the necessary computations for optimal planning and control of the national economy. This was to be a conglomerate of computer centers, on three hierarchical levels, incorporating some time-sharing features along with multiprogramming and multiprocessing. However, the Scientific Research Institute of the Central Statistical Administration, entrusted with implementing this enormously complex system, has absolutely no relevant experience commensurate with the task. It is not surprising that actual plans for this network still remain largely unformulated, in spite of (or because of) interminable discussions about details, ramifications, and proper subordination.

Software development and dissemination of available programs also need organizational restructuring because of the lack of central repositories and publication procedures. The traditional Soviet approach--designing hardware first and only then initiating work on software--still appears predominant, despite claims to the contrary.† The most

†The major Soviet effort to design third-generation computers, the Ryad project, is scheduled to have early models available by 1972. Not until then will it be apparent whether or not this problem has been resolved.

recent attempt at parallel development of hardware and operating software, for the BESM-6 computer system, was only partially successful. The completion deadline was missed by two years because of weak coordination between the organizations responsible for different aspects of software development [9].

Internal criticisms of the problems are abundant. A. P. Ershov, head of Systems Programming at the Siberian Branch of the USSR Academy of Sciences, and the USSR's leading programming expert, stated in 1965 that "there are not enough machines and they are not good enough" [10]. At the important First All-Union Conference on Programming in 1968, Ershov stated flatly that "we are on the 1963 level of world programming, and this five-year gap is increasing" [11]. In 1969, G. I. Marchuk, Director of the Novosibirsk Computer Center, noted that the Soviet Union is in the midst of a "computer famine" resulting from insufficient production of machines, and that utilization of existing computers is hindered by unreliable I/O devices and auxiliary storage [12]. V. M. Glushkov, who heads the Institute of Cybernetics of the Ukrainian Academy of Sciences in Kiev, states that peripheral equipment breaks down practically every day, that data recorded on tape are retained without loss no longer than a month, and that magnetic tapes are not interchangeable among machines [13]. A. Dorodnitsyn, Director of the Computer Center of the USSR Academy of Sciences in Moscow, has complained that during acceptance testing of computer equipment by state commissions the performance of peripheral units could not match prescribed specifications, even with a built-in allowance in their favor [14].

Other critics note the low reliability of such I/O gear as card readers that "require the constant presence of a mechanic," telegraph terminals that have error rates as high as one in every 1000 characters, alphanumeric printers that are checked for only two parameters in a production where only two units per year are tested, and telegraph units that were "rejected by communications people because of their low reliability" [15-16]. As recently as 1968, the following scene could be reported: "A group of workers are gathered around a computer using scissors to cut computer printout sheets while another group binds the sheets manually" [6,17].

Despite all the criticism, little changed between the time of Brezhnev's 1966 speech and his 1971 report to the 24th Congress of the Communist Party, where a significant emphasis was placed on computers. Existing facilities are still inefficiently used, and the number and experience of supporting personnel remain inadequate. These problems directly interface with those of insufficient, incompatible, and unreliable hardware.

III. THE ROLE OF TIME-SHARING IN SOVIET COMPUTING

ADVANTAGES

Time-sharing could be particularly advantageous to the Soviet economic system with its centralized planning and progress monitoring. The State Network of Computer Centers could contribute to more effective management and regulation of production processes by using time-sharing techniques to process incoming data from many lower-echelon production enterprises and then issue updated production directives. A production facility of this type is the goal of the system installed at the Lvov Television factory [18]. Its automatic production system, which is largely Glushkov's achievement, uses two Minsk-22 computers in a time-sharing mode. Fixed programs coordinate the production of television receivers by monitoring every production and assembly station, and vary appropriate schedules to achieve optimum output with preassigned resources. Systems of this type could be generalized for use in many Soviet industrial enterprises because the problems in this sphere are concrete and easily manageable by time-sharing techniques [19].

Time-sharing presents a unique opportunity for more evenly apportioning Soviet computing resources and support personnel, grouping and consolidating machines and people for greater efficiency. It could be the answer to the proliferation of "small computer centers notorious for their primitive methods and inefficient utilization of machines" [6,12]. This is not to say that batch-processing is no longer desirable, but in view of the numerous, outdated, and underused computer systems at industrial establishments and the few, relatively modern, overworked facilities at research institutes, it becomes clear that time-sharing would benefit both types of installations.

Experience with time-sharing systems in the United States suggests that this operating mode dramatically increases computer utilization factors. It is reported that CPU utilization can be brought to at least 50 percent by using time-sharing, as compared to 10-20 percent for conventional batch-processing [20].

The on-line programming that time-sharing systems offer could be a boon to both beginners and experienced programmers. The former could

take advantage of such debugging aids as editin ad er or diagnostic procedures and the latter could enter complex p grams directly into the system. This immediacy of response could r lt in an immense saving in programmer time [20]. It could also rel e programmers of a large amount of unproductive wor and allow them o focus on software development and system programming [6,12]. This may significantly affect Soviet computer technology since about on -half of the investment in modern computer systems is spent on sof are design [21].

Designers of Soviet time-sharing systems vi computer-aided instruction, especially in the field of programming languages, as the only way to cope with the ever-increasing demand for programmers [22]. In principle, therefore, time-sharing offers an portunity for both increasing the thin ranks of support personnel a d improving their productivity.

These advantages undoubtedly attract the at ntion of Soviet designers, offering the possibility of enabling more users to have access to better equipment. But the experts are also aware that only highly productive computer centers, staffed by experienced specialists, will realize the potentials of time-sharing systems [12]. Moreover, computer installations must be run more efficiently to guarantee that computer time will be available when a service request is made by a user at a remote terminal.

COSTS AND PRIORITIES

Although Soviet computer specialists view time-sharing as one way to fulfill the growing need for more and better computing, the increased costs of this computing method may well mean that Soviet government planners consider it a luxury.

It is futile to speculate about budget appropriations for time-sharing development projects. However, if both computing and entire field of automation are considered, we can infer that even though many Soviet observers regard computer technology as an important national resource it has not traditionally been one of their top priorities. Even Brezhnev's 1966 statements give the impression that

the development of computer technology is desirable only insofar as it amplifies the output and quality of mass production and, as such, its growth is correspondingly predestined. The State Plan for the Development of the National Economy of the USSR for the year 1969 stipulated a 90-percent increase in the manufacture of programmed control machines and a 37.5-percent increase in the manufacture of automation equipment. But the projected desirable growth of computer hardware production was given third place with 31 percent [23]. The first hint of a change in priorities is just now emerging. The 1971-75 Five-year Plan calls for a two- to four-fold increase in the output of all types of computing equipment and a two- to six-fold increase in computer production [24]. Nevertheless, computers are emphasized mainly in terms of their effect in increasing industrial output, although more interest is being expressed each year in the computer's role in economic management. Commenting on the 1969 State Plan, K. N. Rudnev, Minister of Instrument Construction, Means of Automation, and Control Systems, stated that "one of the basic trends in the development of technical progress in the Soviet Union is the growing rate of development and introduction of automated production control systems" [25]. In 1969, Marchuk also suggested this sense of priorities when he declared that "the system of large computer centers [time-sharing installations] can operate routinely and productively if we are able to rapidly develop reliable automated control systems which are required for operational planning of the work of enterprises" [12].

Thus, although time-sharing is not neglected in the Soviet Union, neither is it high on the list of priorities in relation to other Soviet computing activities. Nor is it clear at this point, with the Ryad machines still unknown commodities, just how much the inherent capability of these machines for time-sharing operation is or will be exploited.

IV. THE TECHNOLOGICAL BASE FOR TIME-SHARING SYSTEMS

Time-sharing has intensive requirements in terms of hardware and software. It would therefore be beneficial to briefly survey recent Soviet developments in such areas as computers, mass storage media, I/O devices, and computer linguistics to establish whether the existing potential forms a reasonable basis for the expectations of Soviet designers of time-sharing systems.

Note that the Soviets often give contradictory information on equipment specifications and performance statistics. This may be because different users assemble different systems peculiar to their needs, and also because major alterations may be made at sites far removed from the manufacturer. Often, exaggerated specifications are stated before models emerge in their final production versions. Maximum throughput capabilities are often claimed that do not reflect actual operating conditions. Even greater confusion is the rule with I/O equipment and peripheral units. Generally, the newer the equipment, the less is known about it and the less authentic the data.

COMPUTERS

The following Soviet computers, all of which are in production, are suitable to a greater or lesser extent for time-sharing. Their general characteristics and special features are noted.

The BESM-6

The aging (1966 vintage) top-of-the-line Soviet computer, the BESM-6, was designed at the Institute of Precise Mechanical and Computer Engineering (the prototype was assembled at the Academy's Moscow Computer Center) and is being produced at a relatively slow rate at the Moscow Calculating Machines (SAM) Plant.[†]

[†]The number of BESM-6 machines is not known, but is probably no more than a few dozen.

General Characteristics:

Speed: 1,000,000 opns/sec

Word length: 50 (2 for parity check)

Number representation: floating-point binary

Number of addresses: 1

Core capacity: 32K (in eight blocks)

Core cycle time: 2 μsec

Drum capacity: 16 × 32,000 words

Transfer rate: 20 μsec/word

Magnetic tape capacity: 32×10^6 words

Transfer rate: 65 μsec/word

I/O System:

2 Card readers (VU-700): 700 cards/min

4 Papertape readers (FSM-3): 800 char/sec

1 Alphanumeric printer (ATsPU-128): 400 lines/min (128 character positions)

2 Card punches (PI-80-2): 100 cards/min

2 Tape perforators (PL-20-2): 20 char/sec

32 Telegraph units (STA-2M): 382 char/min

The BESM-6's time-sharing capabilities include an interrupt system, a memory protect circuit, and automatic indexing. There are 16 interrupt lines. No published information exists on the distribution of interrupt levels, nor on the possible sources of interrupt signals. Dynamic memory distribution is thought to be implemented by 32 special registers that automatically handle addressing for dynamic memory relocation in 1024-word pages. Any part of the memory may be internally organized into a stack or push-down store. The BESM-6 instructions consist of two groups: (1) arithmetic and logic operations, and (2) conditional and unconditional transfers. Group (1) can access only the first four or last four core pages. Group (2) can access any address directly. To address arbitrary memory locations, instructions must be modified either by the contents of an index register (15 registers operating at 300 nsec) or by first executing special instructions. The stack mode permits execution of some instructions without

indicating operand addresses. Although the BESM-6 features an optional time-sharing operation mode, as of this writing the time-sharing software package has not been completed.

The M-220

This machine is a general-purpose semiconductorized model intended to relieve the overburdened M-20 vacuum tube machine in its wide range of scientific and technical applications.

General Characteristics:

Speed: 25,000 opns/sec
Word length: 45 bits
Number representation: floating-point binary
Number of addresses: 3
Core capacity: 16K (in four blocks)
Core cycle time: not specified
Drum capacity: 64K
Transfer rate: 50,000 words/sec
Tape capacity: 16×16^6 words
Transfer rate: 5000 words/sec

I/O System:

2 Card readers (VU-700): 700 cards/min
2 Card punches (VU-300): 100 cards/min
2 Alphanumeric printers (ATsPU-128): 400 lines/min

The M-220 has a program-interrupt capability, a provision for storing and re-establishing the machine state on command when branching from one program to another, and 18 channels for connections to external devices (originally intended for operation with an analog machine). Address selection and contents are checked by a circuit that monitors a special control bit in every word. Automatic halt results from positive outcome of parity check, which uses an additional bit.

The Minsk-22

The Minsk-22 is a semiconductorized version of the Minsk-2 with expanded I/O capabilities. It is intended for business, production scheduling, and control applications.

General Characteristics:

Speed: 5000-6000 opns/sec

Word length: 37

Number representation: fixed/floating-point binary

Number of addresses: 2

Core capacity: 8K

Core access time: 24 μsec

Tape capacity: 1.6×10^6 words

Transfer rate: 2500 words/sec

I/O System:

1 Papertape reader: 800 lines/sec

1 Punchcard reader: 300 cards/min

1 High-speed numeric printer (TBPM-16/1200): 20 words/sec (13 positions)

2 Tape perforators (PL-20): 20 lines/sec

1 Card punch (PI-80-M): 100 cards/min

1 Alphanumeric printer (ATsPU-128): 400 lines/min

1 Teletype unit (RTA-50): 7 char/sec

Internal and I/O operations are overlapped in the Minsk-22. The program-interrupt feature related to a special instruction makes multiprogramming possible. There is no memory protection and no real-time clock. Only one user channel exists; its intent is unspecified. A later, modified design features a Minsk-1500 data-transmission device that may be hooked into a municipal telephone exchange. The transmission speed on this device is 80 to 140 bytes/sec, with 5 to 8 bits/byte.

The Minsk-23

The Minsk-23 was designed for data processing, but could also handle scientific problems. Its use as a satellite computer in multimachine complexes is often stressed.

General Characteristics:

Speed: (with 8-bit words) 2000-3000 opns/sec

Addition: 300-700 μsec

Multiplication: 1.2-1.5 msec

Logic operations: 120-300 μsec

Word length: variable, between 8 and 32

Number representation: binary-decimal

Number of addresses: variable

Core capacity: 40K (8-bit words)

Core cycle time: 13 μsec

Tape capacity: 44×10^6 words

Transfer rate: 30,000 bits/sec

I/O System:

Card reader: 600 cards/min

Card punch: 100-120 cards/min

Printer: (128 position)--380-420 lines/min

Console typewriter: I/O speed--5-7 char/sec

A multiprogramming mode is a design feature of this computer. Interrupt and pause modes are provided when a transfer is made from one program to another. Restoration of machine state is aided by a special address buffer. Eight programming levels are considered: three user programs, one executive program, one program with extracode instructions (macros), one console typewriter operating program, and two programs for responding to peripheral and internal computer malfunctions. Eight corresponding registers store information required for operating these programs. Fifteen peripheral devices can be hooked to the system and provisions are made for sixty-four such devices. Pauses are organized so that one core cycle time is used to read/write one word into memory with the intervention of a special buffer register.

The Ural Series

The Ural series of computers includes the Ural-11 and Ural-14, in use since 1966, and the Ural-16, undergoing final preparation for production. The Ural computers are designed primarily for economic

applications. They are based on modular design and are fully compatible in structure, circuit realization, and software.

Ural-11 General Characteristics:

Speed: 10,000 opns/sec
Word length: 24
Number representation: fixed-point binary-decimal
Number of addresses: 1
Core capacity: 16K
Core cycle time: not specified
Drum capacity: 40K
Transfer rate: not specified
Tape capacity: 8×10^6 words
Transfer rate: not specified

Ural-11 I/O System:

Card reader: 700 cards/min
Tape reader: 100 lines/sec
Card punch: 120 cards/min
Tape perforator: 20 lines/sec
Printer: 400 lines/min

Ural-14 General Characteristics:

Speed: 10,000-15,000 opns/sec
Word length: 24 n (n = 1-15)
Number representation: fixed/floating-point binary-decimal
Number of addresses: 1
Core capacity: 64K
Core cycle time: 9 μsec
Drum capacity: 180K
Transfer rate: not specified
Tape capacity: 16×10^6 words
Transfer rate: 5300 words/sec

Ural-14 I/O System:

Card reader: 700-1500 cards/min
Tape reader: 2000 lines/sec

Alphanumeric printer (ATsPU-128): 300 lines/min

Printer (narrow carriage): 400-2400 lines/min

Card punch: 100-800 cards/min

Tape perforator: 200 lines/min

The Ural-14 has one interrupt level, one direct subscriber communication channel, a memory protect feature, and circuit state monitoring. Twenty-four external units can be operated simultaneously, and seven programs concurrently.

Ural-16 General Characteristics:

Speed: 50,000-70,000 opns/sec

Word length: 48

Number representation: fixed/floating-point binary

Number of addresses: 1

Core capacity: 64K

Core cycle time: 20 μsec

Drum capacity: 130K

Transfer rate: not specified

Tape capacity: 24×10^6 words

Transfer rate: not specified

Ural-16 I/O System:

Card reader: 3500 cards/min

Tape reader: 1600 lines/sec

Tape perforator: 160 lines/min

Card punch: 960 cards/min

Alphanumeric printer (U-545): 400 lines/min

Seven programs can run concurrently on the Ural-16. There are 64 interrupt levels, a memory protect feature, a real-time clock, and circuit state monitoring. A supervisory program is included. Up to 32 direct communications channels can be hooked up to the system [17].

The Ural series of semiconductorized computers holds promise for time-sharing applications. They are of modular design and thus easily assembled into systems of varying capacities. The blocks and modules are interchangeable. The computers in this series use compatible

software. Reliability characteristics may be enhanced by employing redundancy at the module or the computer level. The following features make the Ural computers appropriate for time-sharing: (1) data-protection circuits, (2) independence of programs sharing the same memory, (3) a system of relative addresses and interrupt and halt systems, (4) a real-time clock, and (5) equipment for interfacing with remote terminals. The Ural series has provisions for absorbing additional drums or discs into the basic system. User problems with these machines appear to have limited their widespread introduction; possibly, they operate considerably below claimed standards.

Later models contemplate using [illegible]K core stores (on Ural-16) and drums with capacities of (0.18-1.44) $\times 10^6$ 14-bit words on Ural-14, and (0.36-1.44) $\times 10^6$ words on Ural-16 at a data-transfer rate of up to 1.5 $\times 10^6$ bits/sec--difficult to believe when one considers present Soviet capability. The prognosis for magnetic disc storage--5-40 $\times 10^6$ 24-bit words with a transfer rate of 400,000 bits/sec--is even more incredible since no operational disc storage unit on any serially produced general-purpose computer has yet been reported in actual use. These numbers must be regarded as long-range forecasts rather than actual achievements.

The Ural-16 is probably intended to have a built-in, multiprogramming, time-sharing capability, indicated by the presence of an executive program responsible for (1) dynamic core memory space allocation according to program priority and status, and (2) protection of one program from another and from itself. The executive also organizes I/O operations.

The software package includes the ARMU autocode (assembler program), designed expressly for Ural-type computers. Translators will be available for ARMU to Ural-11, Ural-14, and Ural-16 machine languages. Translators will also be available for ALGOL-60, ALGAMS, and ALGEC to ARMU.

Third-Generation Systems

The Soviets have two independent projects for developing third-generation equipment. Both have the goal of producing upward-compatible systems of machines based on the concepts of IBM's System/360. The ASVT

project (ASVT stands for "modular computer hardware facilities") is under the aegis of the USSR Ministry of Instrument Construction, Means of Automation, and Control Systems, and is the less ambitious of the two streams. These machines--the M-1000, M-2000, and M-3000--are briefly described in Sec. VI in the discussion of Aeroflot's Sirena-1 airline reservations and ticketing system. The M-series machines are believed to be in or nearing production, but do not seem to present a significant capability for general-purpose time-sharing systems. They will probably find application mainly in special-purpose production control and management information systems.

The Ryad project is the major Soviet effort to break the third-generation barrier. Ostensibly, it is a joint project with various East European countries. In fact, the Soviets are carrying the major portion of the effort, relying on the East Europeans for some peripheral and terminal equipment and electronic components. The system is believed highly similar to the IBM System/360. Prototype units, especially at the lower end of the system's capabilities, are believed to be in the test stage, and the first production test models are scheduled for installation in early 1972. Assuming that (1) these machines perform as anticipated, (2) the Soviets are able to master their efficient production (at the Minsk Ordzhonikidze Plant, where the Minsk series of machines was designed and manufactured), and (3) fully-developed software is available concurrently with hardware production, Ryad holds the most significant promise for time-sharing in the Soviet Union. However, only the most minimal information is available on the Ryad project and no detailed, official announcement has yet been made. Thus, it is premature to speculate about the impact they might have on Soviet time-sharing. It should be pointed out, however, that the known time-sharing development projects do not seem to be counting on the appearance of Ryad to provide the impetus needed for the progress that has eluded them for so long.

INTERNAL STORES

The minimum size of the main memory in time-sharing is twice the amount required by the executive program [20]. Since executive programs

need 8-10K [21], a computer with 16K main memory would meet the minimal requirements of time-sharing. The Soviet computers described above appear, at first glance, to be adequate, at least in the host-slave configurations where the host computer (usually smaller) handles executive program operations, I/O scheduling, and interrupts, while the slave machine (larger, high-speed) performs the actual computations without being required to communicate with slow I/O devices.

However, there are clues that Soviet production of core memories is insufficient to meet demand. Although this problem is not mentioned in the Soviet press, its existence can be surmised by noting that descriptions of even the new computers give the most frugal memory composition, usually accompanied by a note that the core memory is expandable [26]. Core manufacture may not be sufficiently automated to supply the ever-increasing demand. Perhaps this does not appear to the Soviets to be a problem, especially in view of progress made in this area since 1960. L. P. Krayzmer, the top Soviet expert on magnetic storage devices, does not mention this problem in a recent survey [27]. However, we view it as a problem since time-sharing generally requires a larger internal memory and a more massive random-access auxiliary storage.

DISCS

The computers listed above as suitable for time-sharing exhibit a conspicuous absence of magnetic discs. Even in the Ural series, discs are contemplated only for some future date. Marchuk stated that "the main problem in the development of time-sharing systems is the manufacture of highly reliable and large-capacity disc stores for tens and hundreds of millions of words" [12]. This problem is not easily circumvented.

A 1966 University of Illinois study attempts to determine the possibility of designing special-purpose systems with a small main memory that would have slow response times but still provide an improvement over batch-job turnaround times of 2-4 hr [28]. The positive findings reported apply to a system with only 8K + 8K main memory for host and slave computers. However, the system also features a 64K drum and a 9.6M disc memory. Other early time-sharing systems, such

as those at Dartmouth College and the California Institute of Technology, were also complemented by expansive disc stores (IBM words), with access times almost on a par with those of the best Soviet drums [20].

Soviet inability to manufacture disc stores has long been noted; however, disc development is in progress and discs should appear soon. The only mention of a functioning disc is in connection with the Ruta-110 data-processing system [9]. The claimed capacity of 10 disc "blocks" is 10^6 8-bit bytes. A byte access speed of 200 msec and a data-transfer rate of 2000 bytes/sec are featured. No Ruta-110 installations actually using the disc have been noted.

One possible reason for Soviet inability to manufacture disc stores is their traditional lack of expertise in precision electromechanical technology. Another is their inability to manufacture suitable magnetic materials. Many technical articles on recording and reproduction of digital signals indicate that Soviet magnetic coating material for discs and magnetic tapes leaves much to be desired. If we believe the claims of M. V. Keldysh, President of the USSR Academy of Sciences, this situation may soon change. In 1968, Keldysh stated that the alloy material used on tapes in production may surpass Western norms.

I/O EQUIPMENT

There has been no appreciable improvement in the area of I/O equipment since 1966. New designs are appearing only at exhibits and in newspaper announcements. Generally, the press does not associate the new equipment with new computer systems.

A sampling of these new devices illustrates their capabilities. I/O gear announced in the past five years includes PL-80/8A and PL-150 papertape perforators, with speeds of 80 and 150 char/sec, respectively, and the SP-3 papertape reader, with a speed of 220 char/sec. All three were designed at the Severodonets Instrument Building Plant [30]. Other papertape readers include the FSM-ZN and FSN-5 models, with speeds of 1000 char/sec (the former in continuous mode and the latter in start/stop mode), and the FSU-1, with a speed of 200 char/sec. The FSM-ZN

and FSN-5 are produced at the Minsk Ordzhonikidze Factory, whereas the FSU-1 is manufactured at the Ryazan' Calculating-Analytical Machines Plant [31].

No announcements of new telegraph units have been noted except the RTA-60 model, which has a speed of 7-8 char/sec and is associated with the Minsk-22 computer [32]. It has also been impossible to find any reference to typewriters, teletype units, or other gear that would serve as terminal equipment for time-sharing. It is assumed that the Soviets will continue to rely on East European countries, particularly East Germany, for this equipment.

A glance at past performance of I/O devices suggests that the development of adequate terminal equipment can also be expected from the Baltic republics (notably Lithuanian SSR). These republics manufacture electromechanical equipment, such as calculators, desk-top computers, and business-oriented data-processing machinery, that is notably superior to general Soviet equipment of the same type [33].

The Ruta-701 reader (developed in Vilnius) reads typed and handwritten text, and attests to the Lithuanian's ability to undertake the design of reliable, sophisticated, terminal equipment (error rate for typed text is one in 0.5-1 million characters) [34]. Another advanced design, also from Vilnius, is a high-speed multiple-copy printer with a rated speed of 6000 lines/min. This machine will probably replace the ATsPU-128 printer currently used on most recent Soviet computers [35].

SOFTWARE

In the past, the concern of Soviet computer specialists with hardware problems drained research and development resources and led many observers to conclude that the software field was barren. Studies comparing pertinent U.S. and Soviet developments characterized the existing gap as a chasm up to 1968 [9]. However, the long-dormant field of Soviet computer programming, after many false starts (including the publication of the ALGOL-based Alpha, ALGEC, and ALGEM l[illegible]) finally emerged November 1968 at the First All-Union Conference on Programming in Kiev. The proceedings revealed that recent efforts have

resulted in a number of new Russian dialects of ALGOL, and that FORTRAN is being widely adapted to Soviet computers.

The most commonly available compilers are for ALGOL, but many others are being developed and used on such machines as the M-220, BESM-4, and the Ural and Minsk series [36-37]. For example, a FORTRAN compiler for the Minsk-22 machine has been in operation since 1967 at Serpukhov. It takes 13 min to compile 1115 FORTRAN statements on a machine operating at 5000 opns/sec [38]. The STA-2 ALGEM to Minsk-22 machine code translator, whose speed is 80 instructions/min, is in production [39]. The MEI-2 ALGAMS translator for the same machine is also available [40]. A compiler for the ALMO language, with a length of approximately 12,000 instructions and a speed of 120 instructions/min, is provided for such machines as the M-220, M-20, and BESM-4. New algorithms included in this compiler deal with the distribution of data in the main memory and program segmentation [41].

As far as time-sharing software is concerned, Marchuk claims that a number of Academy institutes and other organizations are working in this area. Yu. V. Geronimus, who heads the Laboratory of Material and Technical Supply of the Central Economic Mathematics Institute, is more specific. He reports that the monitor programs DIUR-14-1 and DIUR-16-1 are now being designed for the Ural-14 and Ural-16, respectively [42]. The development of the executive program DIUR-14-2 is already completed (it occupies approximately 8K words); the DIUR-16-2 is nearing completion. These supervisory programs are based on the DIUR language, incompletely specified at present and to be extended in correspondence with the proposed expansion of the Ural-16 computer system. Although more effort is being channeled into software, the persistent shortage of personnel (especially system programmers) makes parallel work on operating systems and time-sharing software impossible in some cases [43]. Also, the new results have not been fully evaluated, and Soviet achievements in this field cannot yet be assessed.

V. ORGANIZATIONAL BASE FOR TIME-SHARING RESEARCH

In evaluating the qualifications and resources of institutions with the potential to undertake the development of a general-purpose time-sharing system, four major computer research facilities are prominent. These are discussed below.

With the exception of work in progress since 1966 in Novosibirsk and experimentation at a relatively unknown institute in Kazan', the available Soviet literature contains no indication of operational, general-purpose time-sharing systems with the capability to run programs entered from user terminals.

COMPUTER CENTER OF THE SIBERIAN BRANCH OF THE USSR ACADEMY OF SCIENCES†

This institution, located in Novosibirsk and under Marchuk's direction, engages in time-sharing via project AIST (automatic information station). Other avenues to high-productivity computing based on multiprocessing concepts were explored here and generated great interest for a time [44]. The Novosibirsk Computer Center is staffed by approximately 480 people, half of whom have advanced degrees. Its Systems Programming Section, under Ershov's direction as technical manager of the AIST project, consists of 30 people [45].

INSTITUTE OF APPLIED MATHEMATICS

Headed by M. V. Keldysh and located in Moscow, this institute was one of the first to receive a BESM-6 model and presumably engages in time-sharing work. Almost nothing is known about its manpower composition or activities. However, it is speculated that its work is related to the Soviet space effort.

COMPUTER CENTER OF THE USSR ACADEMY OF SCIENCES

Located in Moscow and headed by A. A. Dorodnitsyn, this center was instrumental in assembling the BESM-6 prototype and in writing the

†Hereafter referred to as the Novosibirsk Computer Center.

first (unsuccessful) operating system for that machine. It has been speculated that time-sharing software for the BESM-6 is being developed here [43]. However, the paucity of information emanating from this institution, combined with other indications, suggests that the BESM-6 will not be operated on a time-shared basis at this location [45].

INSTITUTE OF CYBERNETICS OF THE UKRAINIAN ACADEMY OF SCIENCES

Located in Kiev and under Glushkov's direction, this institute engages in a variety of projects closely related to time-sharing. There are indications that the small Mir-2 computer designed here may be used in conjunction with large computers in a time-sharing mode, transferring its job to the larger machine only if its limited speed and storage prove insufficient [46]. The Institute also engages in research on automation of language design, that is, optimization of algorithms used in translating higher-level languages to machine codes, and the development of machine languages closer in structure to source languages. The Institute's involvement in the implementation of computer-based production control and management systems, such as at the Lvov Television factory, is described in Sec. VI.

The manpower composition at this institute cannot be explicitly stated since a large part of the development work is done at a closely related special design bureau and at the Kiev Computer and Control Machines Plant.

VI. SOVIET EXPERIMENTS IN TIME-SHARING

This section examines current activities in time-sharing as reflected in the available Soviet technical literature. The embryonic stage of the work is characterized by an emphasis on systems using existing hardware and by the lack of work on time-sharing software. As could be expected, more progress is being made in special-purpose than in general-purpose time-sharing systems. However, it may be significant that the major computer research institutions in Novosibirsk, Moscow, and Kiev are paying increasing attention to this computational mode.

PROJECT AIST

Project AIST[†] was proposed in early 1966 in conjunction with discussion on the establishment of the State Network of Computer Centers included in the Five-year Plan for 1966-1970 [47-48]. This project aims at developing theories and techniques for designing automatic information stations, i.e., large- and medium-scale computer complexes interconnected by communication lines, with a large number of information sources and users concurrently processing the information in a time-sharing mode. Theoretical research and development of AIST was to be supplemented by operational tests of working AIST models based on computer resources available at the Novosibirsk Computer Center.

The AIST project was to be conducted in two stages. The first-priority AIST-0 subproject called for the development of a time-sharing system using one Minsk-22 computer as a communication controller (or monitor) housing the executive program, and two M-220 computers with expanded core stores functioning as central processors and operating both in the time-sharing and batch-processing modes. Ten to fifteen teletypes, one or two off-line data I/O units, and two or three remote data terminals were initially planned for this system.

[†]The acronym AIST--automatic information station--forms the Russian word for "stork."

The AIST-1 station would be developed after completion of AIST-0. AIST-1 would be a maximum capability, general-purpose time-sharing system with extensive programming facilities and a large number of different types of communication channels. Its CPU would consist of one or two BESM-6 machines with main memories expanded to 64K words. As secondary storage, drums with a total capacity of 10^6 words and discs with a maximum capacity of 10×10^6 words were projected. Either an M-220 or a Ural-14 machine would be used as a communication controller. Terminals with the following configuration were planned: 150-200 teletype units; 10 display consoles; 15-20 off-line I/O units; 5-10 channels for interconnection with transducers operating in real time; and 5-10 channels reserved for remote users, some with wide-band facilities (up to several kHz).

The AIST-0 was to be operational in 1967 and the AIST-1 sometime in 1969, in time for the Five-year Plan deadline. After project completion, the resulting systems of both AIST-0 and AIST-1 were to be retained by the Novosibirsk Computer Center as part of its permanent computing facility. As of this writing, AIST-0 does not appear to have been completed, although the two portions of AIST, AIST-0 and AIST-1, may have been merged into a single, concurrent development program.

AIST development was to encompass statistical analyses of reliability, internal and external information flow, and determination of their main parameters, with AIST-1 incorporating useful ideas and findings derived from AIST-0. All known processor configurations and executive programs were to be reproduced and tested in operation, along with I/O control systems, schemes for data swapping between main memory and secondary storage, and various job-scheduling and priority-assignment algorithms.

Its designers recognized that the AIST project depended upon computer models available at the Novosibirsk Computer Center, and that one of the most difficult tasks was the development of appropriate software. Therefore, software development was initiated immediately after project inception.

The time-sharing software package envisioned at that time included (1) a general-purpose executive program to facilitate interaction between the user and the AIST station and to organize information exchange with off-line I/O units; (2) a system of programming and debugging with symbolic addresses, possibly using the SIGMA symbolic generator and macro-assembler; (3) an ALGOL-based programming and debugging system using a specially designed incremental compiler in conversational mode; and (4) a general-purpose system for executing analytical operations in an on-line conversational mode. The software also included a programmed instruction system and, if the secondary storage proved sufficient, some sort of data-retrieval system, possibly using information on AIST as the data base.

It is not certain which final configuration was adopted for the AIST-0, but since much of its structure depended on the computers available at the Novosibirsk Computer Center, periodic progress reports (the last available one is dated August 25, 1967) probably reflect the actual emerging outlines of the AIST-0 system.

The block diagram of the AIST-0 system (Fig. 1) is from one of the first progress reports [22]. In general, the system operates as follows: The Minsk-22 computer is used as a monitor where the executive, which coordinates all internal operations, resides. The two M-220 computers are used as the CPU, which executes computations in conjunction with the main memory. A section of the main memory is used as a buffer for I/O signals, which are sent or received from either the main memory or secondary storage, depending on program status and priority. Another main memory section is used as a buffer for data transfer to other units of the system and for relocation of programs within the main memory. The secondary storage, comprising four magnetic drums and four magnetic tape units, has its usual function. Other units in the system are used for interfacing and directing control signals.

Specific descriptions of each system component involve some uncertainty since the available literature, in the form of progress reports, is incomplete. These reports were only issued for some units and indicated major changes as the development progressed. Modifications were very likely made on other units but, because we have no

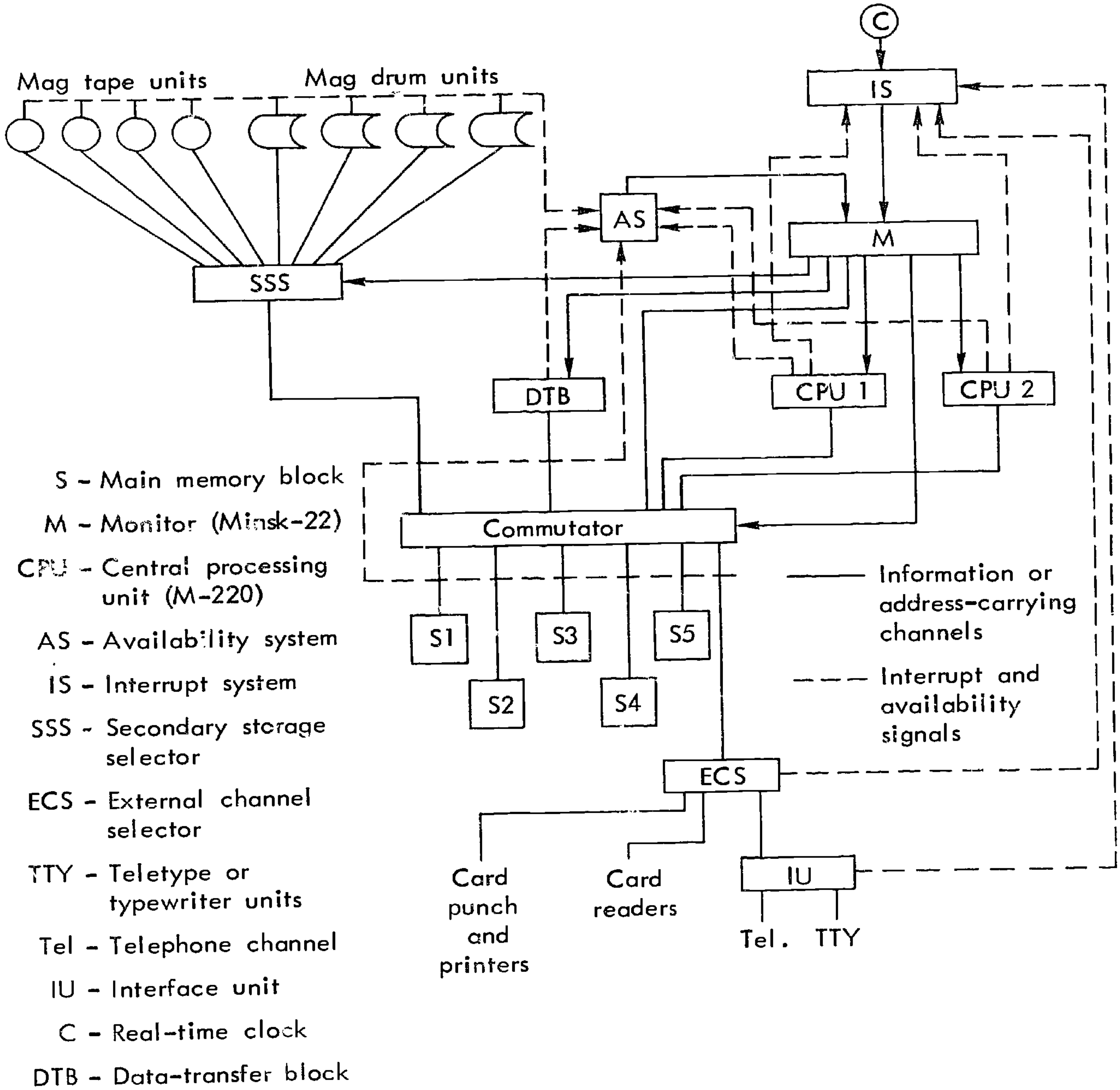

Fig. 1--AIST-0 System

up-to-date information, the detailed description may not represent the actual design.

The *commutator* [22,48-49] interfaces all active system components (monitor, CPUs, secondary storage selector, and external channel selector) with the common main memory, which is organized in 6 banks, each able to accommodate 1 to 4 core memory blocks containing 4096 words each. Each bank functions independently and may be selected through the local control and switching unit. Each is individually connected to the commutator; thus, in practice, six active units may be concurrently linked to six main memory banks, in any configuration. These units cannot directly interact with one another, but must use the facilities of one of the banks, which serves as a buffer for data transfer.

The configuration of commutator connections is at all times specified by the monitor in terms of control words and special instructions. Every active unit contains a special register that stores the number of the main memory bank with which it is interacting. Thus, the desired connections are made by the monitor, which sends the required addressing information to the commutator through the above registers.

The commutator's design makes it possible for several active units to interact with one main memory bank by using the time-sharing principle. The sequence of connections is defined by the priority and status of each active unit.

Data channels interconnecting the commutator with active units transmit 48-bit information words in both directions (45 information bits, 2 check bits, and 1 spare bit). Twenty addressing channels transmit 19-bit control words, in the direction of the commutator only (2 bits to indicate main memory bank number, 2 bits for the block number in the main memory bank, 12-bit address for storage location in one block, 1 bit indicating whether read or write mode is desired, 1 bit to initiate memory bank access, and 1 bit as a service request signal). A signal indicating that a request has been serviced is sent back to each active unit. A channel between the commutator and the main memory transmits a 48-bit information word and 17-bit address and control signals.

This addressing scheme suggests that the main memory is expandable to 64K, excluding the sections used as I/O buffer and for data transfer. A scheduling chart in a report by Yu. V. Metlyaev set the completion date for this unit at the beginning of 1968 [49].

The *external channel selector* (ECS) [22,48,50] interconnects user terminals with internal AIST-0 system units (monitor, CPU, main memory via the commutator, and secondary storage via the secondary storage selector (SSS)). It also facilitates automatic (i.e., without executive intervention) reception of data from users and entry of these data in the I/O buffer memory block and vice versa. The ECS also generates servicing signals that coordinate system operation.

Thirty-two external terminals can be accommodated, in the following configuration:

1. One VU-700 card reader with an input speed of 700 cards/min.
2. Two ATsPU-128 alphanumeric printers, with speeds of 400 lines/min.
3. Four 1200-baud telephone channels, presumably in conjunction with modems, with such terminal equipment as the FSM-ZN paper-tape reader (maximum speed 1000 char/sec) and the PL-150 tape perforator (maximum speed 150 char/sec) [51].
4. One PI-80 card punch, with a speed of 100-120 cards/min [52].
5. Twenty-four teletype units or electric typewriters (unspecified), with approximate transmission rates of 50 bauds.

The information transmitted to and from terminals is stored in the main memory I/O buffer block, which may be any one of the main memory blocks assigned by the monitor, which sends an appropriate code to a special commutator register. Other active units may have access to the I/O buffer block, which is intimately associated with the ECS, but only the SSS has a higher priority than the ECS in this respect.

Sixty-two parallel channels leading from the ECS to the commutator provide transmission facilities for 48-bit information words, 12-bit addresses, one channel for transmission of the "read-write" signal, and one channel for the "connection request" signal. In the reverse direction, 48-bit information words and the "connection enable" signal can be transmitted.

The ECS (1) controls the I/O buffer memory block, (2) establishes correspondence between active user terminals and their identifying numbers, and (3) converts control symbols (such as "carriage return" and "end of text") into interrupt signals through a number of registers. The most important of these registers are

1. *Service request register*: Receives service requests (synchronizing pulses) from terminals and generates interrupt signals from "carriage return," "end of text," and "half zone" signals. A zone refers to the memory space in the main memory I/O buffer block allotted to each terminal device--card reader (256-cell zone), alphanumeric printers (512 cells), telephone channels (1024 cells), card punches (256 cells), and teletype or typewriter units (768 cells), a total of 2816 cells.
2. *Communications register*: Controls data exchange between commutator and I/O buffer registers.
3. *I/O buffer register block*: Comprises 32 registers, one for each channel.

In addition, the ECS contains (1) a counter for words and bytes that generates addresses for storage locations in the main memory I/O buffer block for every terminal device, and (2) a unit for presetting base addresses in the I/O buffer block. The latter is done manually so that buffer zones may be varied in both length and relative position in the memory.

Each zone in the main memory I/O buffer block is split into two half zones, with one receiving information from user terminals while the other transmits information to magnetic drums or the main memory, and vice versa, under the auspices of the executive.

Main memory for the AIST-0 [22,48-49] consists of standard M-220 computer memory blocks (4K capacity and 6-μsec access time), organized in banks accommodating 1 to 4 blocks each. It is not clear whether four, five, or six banks comprise the main memory proper, or whether only four are used in this function, with single-block banks as the I/O and data-transfer buffers. However, regardless of their functions, all banks are connected to the commutator unit and the addressing scheme

limits the total AIST-0 memory capacity to 64K, even though 80K was envisioned earlier [22].

The *data-transfer block* [22,48] is both a working buffer storage and a means for exchanging information, grouped in sections, between separate main memory banks. (It is uncertain whether a paging system is implied here.) The data-transfer block incorporates its own control unit, thus facilitating group exchange of information and freeing the monitor from this task. The control unit has an address register (containing the address of the last word transmitted) and two counters (containing the current address of the data-transfer block and the current address of the main memory, or ECS block, i.e., the I/O buffer block).

The monitor initiates information exchange when the data-transfer block is in a state of readiness. When group data exchange terminates, the control unit restores the data-transfer block to the availability state.

The *SSS* [22,48,53] controls information exchange between the main memory and secondary storage, which includes four Ural-4 magnetic drums and four magnetic tape units (with word transfer rates of approximately 20,000 words/sec and 4000 words/sec, respectively). Each group of storage units of the same type has a local control unit coupled to the SSS through a channel transmitting 8-bit bytes in parallel-series mode. One channel, which transmits 48-bit information words in parallel to and from the secondary storage and main memory, is time-shared by all secondary storage units. In addition, addressing information and data-transfer direction signals are transmitted from the SSS to the main memory. The SSS may be viewed as a time-multiplexing unit permitting concurrent data exchange between an arbitrary secondary storage unit and all main memory blocks, including the I/O buffer block. Every secondary storage unit has a buffer store equal to three words, two used as the buffer proper and one for storing control word and starting pulses from the monitor.

Information exchange via the SSS is organized as follows. The monitor initially defines the necessity for and possibility of organizing data exchange along a certain channel. The channel is activated

when the monitor transmits a control word to the SSS and a conditioning code to the local control unit of the corresponding group of secondary storage units. The control word contains the initial and final addresses of an information array in the main memory, as well as the number identifying the main memory bank. The conditioning codes contain (1) initial addresses for information arrays on magnetic tapes, (2) indicators of data-transfer direction (read or write), and (3) the numbers of the channels over which data exchange is to be conducted. The SSS local control unit decodes the conditioning codes, activates the required storage units, and locates initial unfilled data-storage zones. During information exchange with the SSS, the local control unit also determines when to transfer the entire 48-bit word. When data transfer is accomplished, the local control unit restores all participating subunits to their initial states and sends a signal indicating availability to the interrupt system. The SSS cyclically samples secondary storage channels and, when required, transmits or receives information bytes along corresponding channels, stores and modifies control words during sequential operation with the main memory, and converts the 48-bit parallel information into parallel-series code (grouped into 8-bit bytes), and vice versa.

The *CPUs* [22,48] are two M-220 arithmetic and control units, modified for time-sharing as follows:

1. Intermediate registers were added to control units to provide the information link between the monitor and the processor control registers.
2. CPU design allows it to stop its operation and send an interrupt signal during execution of any instruction or at the onset of a situation that changes the CPU's orientation with respect to the external world (e.g., halt or overflow conditions, conditional halt, reception of a corresponding instruction from control console). In certain types of halt situations (not fully ascertained as of this writing), the CPU also sends a signal indicating availability restoration.
3. The CPU was designed so that the monitor could put it into operation in different modes.

The processor physical connections allow individual processors to be operated autonomously and disconnected for maintenance and repair.

The *monitor* [22,48] is a Minsk-22 CPU with two memory blocks (8K total capacity, 24-μsec access time). The selection of this machine was dictated by the equipment available at the Novosibirsk Computer Center. The control unit required the following substantial additions:

1. Two additional registers for information words and addresses were built to make it possible to transmit data to active system units (SSS, data-transfer block, and CPU) and the commutator itself;
2. The monitor was interconnected with interrupt and availability systems;
3. An assortment of system instructions for transfer of control words was added to the machine's repertoire to facilitate contact with the commutator, control of active units, addressing of interrupt and availability systems, and contact with the real-time clock.

The modified monitor is able to activate or stop any AIST-0 unit by sending a control word or a combination of control signals to the local control unit. The information link between the monitor and other station units consists of an intermediate 48-bit register and corresponding, independently addressable communications registers (present in every unit). The required communications register is selected by a decoder built into the monitor. The decoder specifies the mode of operation of each station unit. In addition, a 14-bit address register, built into the monitor, governs commutator operation.

The *interrupt and availability system* [22,54] is functionally divided into two parts: interrupt and availability registers.

The interrupt register consists of 32 individually addressable registers, subdivided into 8-bit sections. Service requests automatically interrupt the monitor and are grouped in this register according to three priority categories: (1) requests requiring immediate executive intervention (e.g., signals indicating that I/O buffer zones are full, carriage return signals); (2) requests not requiring immediate

executive attention (CPU signals, user service requests, etc.); and (3) monitor interrupt signals to the monitor itself.

The availability system includes passive signals characterizing the internal state of station units, i.e., whether or not they are in a state of readiness. The executive addresses this register on its own initiative, according to need.

The *real-time clock* [22] includes a source of periodic signals and reversible counters to which these signals are applied. The counters provide interrupt signals at their outputs when a count of zero is reached. They may either be set by the monitor for an arbitrary length of time or by the periodic signal generator for preset intervals. The number of counters and time quanta are not yet specified in the system, but from the proposed job-scheduling algorithms it is known that variable quanta are considered.

The *statistics collection system* [22,55] is not shown in Fig. 1. It includes built-in hardware and software components and will be used to gather dynamic data of AIST-0 system operation, as characterized by such variables as the quantity, volume, and direction of information transmission, loading factors of active units, interrupt frequencies and the speed of request servicing, reaction times of the system from the user's viewpoint, and queueing characteristics. The statistical data on these factors will be subjected to preliminary internal analysis, compressed, and recorded on magnetic tape.

In addition to the limitations faced by the Novosibirsk designers of AIST-0 with respect to equipment availability, the development of time-sharing software had to be initiated from scratch, since in 1966 no other Soviet organization was conducting relevant work in this area. This work was still incomplete as of November 1968 [56-57], and no formal announcement of its completion has since been made.

AIST-0 time-sharing software performs such functions as I/O control, job scheduling, handling of priorities, program swapping between main memory and secondary storage, control of I/O for running user programs, and various service operations. In addition, it must perform on-line compiling and debugging, most of which must be handled by the Minsk-22 monitor with its limited main memory (8K words) and relatively slow

speed (10,000 logic opns/sec). There is no assurance that present software specifics will be incorporated in the final design; however, alternatives are available [22,55,58]. For example, the job-scheduling algorithm proposed for AIST-0, with its resulting floating time quanta, involves a choice of an optimum mix between two types of scheduling algorithms: (1) an algorithm based on the preference principle, i.e., the shortest program is serviced first or the highest priority is assigned to the job residing longest in the system; and (2) an algorithm based on minimal cost function, defined in terms of estimated time, t, needed for a particular job execution and the cost, c, per unit time of keeping the job in the system, where neither quantity is precisely known because statistical data are not available. In one design proposal, the mix of these algorithms can be altered during the course of AIST-0 operation.

Another set of design alternatives is to make appropriate distribution of storage for system programs among the monitor memory, the main memory section subject to swapping (estimated net swapping time for 4K words is ~400 msec), and the main memory section reserved for permanently stored system subroutines. Storage of system programs only in the monitor releases processor-associated memory space for other users but, on the other hand, increases the reaction times of both system programs and the executive program when both are crowded in the slow monitor. It is believed that the choice was made to store system programs only in the monitor. However, monitor capabilities are limited and estimated response times for such system programs as debugging routines, incremental compiler, editor, and analytic analysis program are in the range of 1-10 sec, or 1-10 min, depending on the type of program.

It is not clear how dynamic memory allocation and program relocation are to be implemented. Although a paging system is contemplated, page size is unspecified; several standard sizes are considered, with provisions made to group these according to need.

Certain system programs for AIST-0 have been completed but not yet debugged. One of these is the FON system program used as a manager for batch programs that run in the background. The FON program (1) organizes user service requests, written in a language peculiar to FON,

(2) forms a queue, and (3) feeds these jobs to the CPU. The queue is formed on the basis of a job's entry time into the batch queue, the time required for its execution, and the relationship between the required and available memory resources at job execution time.

The AIST-0 system includes a specially designed incremental compiler using ALGOL for source statements. The system reacts with the user in the conversational mode when errors need attention or information is missing. This system program will be organized for time-sharing.

Another incremental compiler operating in conjunction with the symbolic generator and macro-assembler (SIGMA) machine-oriented language is being designed. No serious difficulties are anticipated here since statement processing (one at a time) involves only recoding the source information and, as such, is similar to an assembler, which is relatively easy to design.

In addition to the system programs mentioned above, AIST-0 also contains (1) a file-maintenance program, (2) a so-called analytic analysis program, and (3) a symbolic debugging system.

The *file maintenance program* for individual user files can be updated or deleted in sections based on lines, words, or pages.

The *analytic analysis program* makes it possible to differentiate, integrate with the aid of integral tables, operate on polynomials, make substitutions and simplifications, etc., from an on-line terminal in a conversational mode. This system program stores analytic instructions for subsequent automatic execution in an interpretive mode.

The *symbolic debugging system* provides the capability to enter and debug M-220 machine programs from terminals. This program (sometimes called the Consultant) provides questions and answers that allow the user to discover his mistakes through a sequence of ordered debugging steps.

The development of the AIST-0 system is probably encountering snags in the time-sharing software area. The monitor and the working processors use different word lengths, vary in their speeds, and require rigid division of functions between them. The fact that no magnetic discs are available in the system complicates executive program design and makes it mandatory to tape-orient the user file system.

This in turn requires placing intermediate files on magnetic drums to reduce response time. It is difficult to judge the effect of this arrangement on program queueing and swapping operations, but it is clear that the executive must be more carefully designed to ensure the required response time. In 1967, Marchuk noted the desirability of magnetic discs and hoped that IBM discs could be purchased [59]. However, at present it is more likely that discs from Western Europe will be (or are being) used.

In U.S. time-sharing systems (PDP-10, SDS-940, and GE-420), the average memory space allotted to the executive is approximately 12K for every 30K of main memory. The Minsk-22 contains an 8K monitor in a system with a 64K main memory (the total main memory capacity for the AIST-0 station) [21]. If this ratio is considered an index of executive efficiency and versatility, then the AIST-0 executive is both very compact and able to perform a large variety of control functions. However, even the incomplete evidence available suggests this is not the case. A design policy is being considered where a portion of the executive is stored in the 64K-word main memory section, even though this gives rise to addressing problems because of CPU and monitor incompatibility. In addition, extending the executive well beyond 10K to ensure a wider time-sharing software capability runs the risk of too much sophistication. The IBM 360/67 proved this by showing that a high rate of page traffic between main memory and secondary storage reduces the efficiency inherent in a time-sharing system. On the other hand, keeping the executive only in the Minsk-22 memory may curtail some of its functions and diminish the system's versatility.

Time-sharing places great stress on all system components. Because many users are concurrently affected, all subsystems must harmoniously interact in an error-free, secure environment. Therefore, the AIST-0 system presents a real proving ground for Soviet computer technology.

In 1966, Ershov saw the AIST project serving such lofty purposes as (1) providing a technical means for mutual adaptation between man and machine; (2) making it possible to bridge the gap between users' narrow fields of interest and the vast amount of supporting information

required; and (3) providing a means whereby the inclusion of man in the data-processing loop would make it possible to better utilize his heuristic talents and algorithmic machine capabilities. Unfortunately, the AIST project does not seem to be fulfilling these purposes. Instead, man is adapting to the lack of machines, and his heuristic talents are fully occupied with making the existing equipment perform approximately as stipulated in the system specifications.

ACADEMY COMPUTER CENTER, MOSCOW

In 1966, the press widely publicized the BESM-6's association with the Academy Computer Center, which had assembled and debugged the first prototype. Unprecedented picture coverage was given the first Soviet computer to break the 1,000,000-opns/sec barrier. Since then, however, news about the BESM-6 has become relatively scarce in both the popular press and the scientific literature. Although the BESM-6 was designed with a potential time-sharing capability for servicing up to 100 remote terminals, it is not operated in this mode at any known installation. In 1967, a Western observer reported that the BESM-6's time-sharing capability would be explored in Moscow and that East German typewriter terminals were being considered [2]. Apparently, this was given secondary priority in favor of the general operating system, which had to be rewritten because of the inadequacy of the first system supplied with the prototype model. The new operating system, primarily oriented toward batch-processing, was announced and described at the 1968 Kiev Conference on Programming [60]. The new software package includes an executive, a monitor, loader systems, FORTRAN and SUBSET ALGOL-60 compilers, an autocoder for the SIBESM-6 language, and a system for using library subroutines. The personnel at the Academy Computer Center appear to have been totally engrossed in developing the operating system and were therefore unable to devote any time to time-sharing. On the other hand, it may be that the development of time-sharing software was initiated elsewhere. A 1968 meeting of the Presidium of the USSR Academy of Sciences contained two factions: one espoused the idea that, because of a personnel shortage, the Computer Center should carry out only basic

software research and relegate actual development to computer manufacturers; the second faction favored having the Center do both research and development, as well as perform various computational needs of the Academy institutes [43].

There have been no published complaints of BESM-6 inadequacies, but a 1969 article questions the use of ultra-high-speed local stores, such as in the BESM-6 [61].

Because concrete figures are not available, we will not contest the reliability of the BESM-6. The model at the Computer Center operates about 22 hr/day, with 1 hr/day devoted to scheduled maintenance [45]. The use of such notoriously unreliable I/O devices as VU-700 card readers, PL-20 tape perforators, PI-80 cardpunches, and FSM-3 papertape readers emphasizes the fact that effective reliability of computer systems still depends on the reliability of I/O gear. This condition is especially intolerable in the time-sharing environment; I/O devices more in keeping with faster CPU models must be developed. This may be one reason a visual display unit is being designed at the Academy Computer Center, presumably for the BESM-6 [62].

The development of visual display units was anticipated by the AIST project leaders, who planned to use them with the BESM-6-based system. This unit will use the BESM-6 main memory to convert machine-coded information into alphanumeric or graphic form and display it on a standard television screen, using a 400 by 400-point raster. Up to 1200 symbols may be displayed, including Latin and cyrillic literals, numbers, and special characters. The design features a unique image-regeneration scheme that eliminates flicker and image fading, saving CPU or local memory time. The display information is composed into raster form by a special program located in the main memory; it is then transferred to a magnetic drum. The data for the entire raster occupy two or four drum tracks; a full flicker-free frame is formed in two drum revolutions, at a rate approximately equal to 24 Hz. Each frame may include up to 24 lines of 50 symbols each. Any symbol in the display may be changed through a keyboard; this would permit users to correct programs on-line.

Although BESM-6 designers spoke of 100 remote terminals, only 16 programs can concurrently share the BESM-6 memory. There is no mention

of a multiplexing unit or a communication controller to facilitate communication with other units. However, it is known that the AIST-1 project calls for a separate computer to handle this activity. This seems to indicate that perhaps the BESM-6 requires a certain amount of new hardware system organization in addition to the time-sharing software. The available literature does not indicate that the Academy Computer Center is actively engaged in such work. However, the Center's interest in visual display for time-sharing means that new solutions to the I/O situation are finally being explored.

KAZAN' M-220 SYSTEM

The Kazan' State Institute of Scientific Research and Design for Introduction of Computer Technology into the National Economy is a little-known organization that came into prominence on the basis of a joint presentation by R. M. Kasimov and Yu. P. Kuzovlev of a paper entitled "A Time-Sharing System for Servicing an Enterprise" [63], offered at the First All-Union Conference on Programming. The authors describe a developed and presumably operating time-sharing system.

The first mention of the Kazan' project was included in an inconspicuous article by Kasimov buried in the Notes section of the journal *Economics and Mathematical Methods* [64]. The article, submitted for publication in late 1967, describes successful preliminary attempts to design an experimental time-sharing system using a medium-capacity computer of the M-20 family.† It focuses on the feasibility of providing time-sharing through the use of medium-capacity computers and examines the terminal equipment required. The computer considered would have a 16K main memory, 64K magnetic drum, and 16M magnetic-tape capacity. The terminal equipment would be based on the East German "Soemtron" typewriter, with a rated speed of 7-8 char/sec. The use of STA and RTA telegraph equipment was contemplated, but not seriously because of the small character sets they contain and the extensive equipment modifications required by the three-register keyboards.

†Which could mean M-220 or BESM-4.

A subsequent article by Kuzovlev devoted to the software for this system appears in the next issue of the same journal, but makes no reference to the preceding article [65]. However, the use of medium-capacity computers in time-sharing is noted in a comment that, in such systems, it is desirable to reduce the magnetic drum access time to 10-40 msec for transfer of 4-8K words.

The operating system described includes a monitor system for user interaction with the system, one or several programming languages for problem presentation, and an executive that would allocate time and memory space between users and provide memory protection. The executive consists of several subroutines and is activated both by an interrupt system and by macro instructions in user programs.

The executive controls (1) a block for servicing independent units (CPU magnetic drum and tape, card punch, printer, etc.) for purposes of organizing queues and executing requests from user programs and the executive making use of these units; (2) a real-time clock block, which times the duration of CPU utilization by user programs, keeps track of available and down-times of various independent units for accounting purposes, and checks the operation of programs, units, and terminals; and (3) a scheduling block, which assigns the sequence for requests waiting for available CPU time, defines the time-slice duration for each job, and controls the swapping of user programs.

The monitor is subservient to the executive, and oversees the following blocks:

1. *System input block*: Requests user's surname and password, determines whether the user has a right to access programs and files contained in the system, and reserves main memory space and necessary equipment;
2. *File retrieval block*: Loads requested programs or data into the main memory;
3. *Program execution and halt blocks*: Controlled from the user terminals;
4. *Program terminate block*: Sends a signal to the user that his program has been executed and has left the CPU;

5. *Contact termination block*: Transmits data to the user, e.g., duration of interaction, number of magnetic drum accesses, duration of operations using CPU and magnetic tape units, etc.

The number of user programming languages is limited only by the editing capabilities of the compiler used with this system.

The tone of the article leads us to believe that only a feasibility study was made to determine the software requirements for a small-scale, general-purpose time-sharing system. The system is characterized by (1) a simple command language that could be learned through a programmed instruction mode accessible from user terminals, (2) one file that stores system programs, subroutines, and the necessary information for the conversational mode, and (3) an operating-system structure that permits system expansion in terms of number of users and equipment composition.

Based on their joint paper at the All-Union Conference on Programming, it is clear that Kazimov and Kuzovlev are working on the same system, and that rather than being a feasibility study for a computer of the "M-20 type," it is based on an actual machine, the M-220, and an actual development program. The software has been developed to such a degree that the syntax for the various languages used is fully specified [63].

The Kazan' time-sharing system (see Fig. 2) had to (1) accommodate both time-sharing and batch-processing computing modes, (2) be expandable in terms of number of terminals, (3) be able to operate with terminals based on Soviet components, and (4) utilize a general-purpose language for man-machine interaction. In order to meet these requirements, the system architecture uses an M-220 computer as the CPU, modified by adding facilities for memory protection, unconditional halt, instructions requiring long execution times (e.g., for data input and magnetic tape access), and a real-time clock.

The modified M-220 features two operating modes, the system and the user modes. The user mode has a higher priority. The terminals consist of RTA-50 teletype units, with control boxes used for establishing the connection with the system. The channel commutator provides for connection of a terminal when at least one of the eight

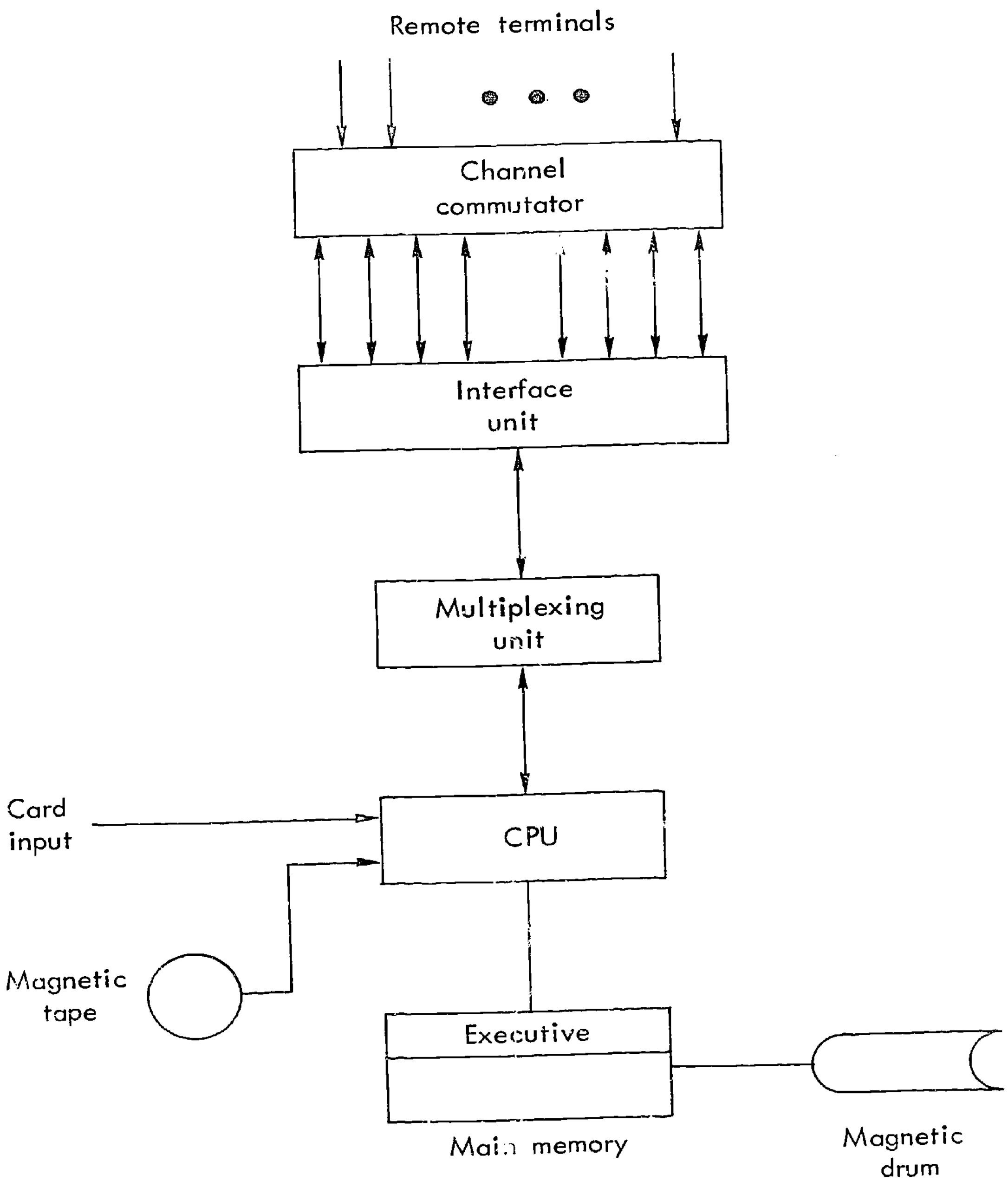

Fig. 2--The Kazan' Time-sharing System

internal channels is unoccupied. Provision has been made to expand the number of internal channels to 16. The maximum number of users can be much greater, but a maximum of only 8 (or 16) can be on-line at any one time.

The interface unit converts five-unit serial telegraph code into parallel code, and vice versa. It also generates interrupt signals after reception of each telegraph character or before each character is sent to the terminal.

The multiplexing unit organizes information exchange between the CPU and the interface unit. It contains a channel-number decoder and corresponding gates for routing information to the required channel. It is a half-duplex device in that data flow for a particular channel is in one direction at a time. The multiplexing unit also includes circuits for interfacing with an analog computer--a feature provided for in the M-220 computer design.

The M-220 is believed to have the following minimum memory and storage size requirements, related to the number of user terminals: 4K core memory and 24K magnetic drum for a system interacting concurrently with 8 users. In this configuration, the executive takes up half the main memory space; the other half is reserved for one user program. All other user programs, regardless of status, are currently stored on magnetic drum. A section of 16K words is reserved for this purpose, with the remaining drum-storage space used for system programs and a library of standard subroutines. The executive portion of the main memory also contains 16 I/O sections for storing up to 16 × 108 teletype symbols. One of four tape units may be used as an extended main memory to store the executive, service subroutines, long texts, and individual files.

When the CPU becomes available for a particular user's program in a queue, the program is transferred from the magnetic drum to the main memory and execution takes place until (1) completion (computations are terminated, I/O to terminal or magnetic tape access is required); (2) an emergency situation arises; or (3) a 10-sec time quantum (fixed in this system) elapses.

The time-sharing software for this system consists of the executive and the input language, the latter subdivided into two levels. The first level, the executive command language, is implemented by the monitor program. It controls the computation process and selects services from a library. The executive command language consists of eight instructions, with appropriate identifiers. The second level, the service language, is implemented by the input editing service subroutine.

When a user requires programmed instructions to learn the use of the command language, a special teletype symbol (*) can be used, at any point in the dialog, to call in the monitor. All monitor subroutines are thereby interconnected into a single complex in required sequence. Questions extract the necessary information from the user, for example:

Monitor: DO YOU KNOW HOW TO USE THIS SYSTEM/TYPE YES OR NO ONLY/

User: NO

The service language provides access to specific services. It is a general-purpose language, limited only by the teletype keyboard symbols. It is therefore possible to include syntax contr... in compilers for algorithmic (higher-level) and problem-oriented languages. The basis of this language is a message considered as a user's reaction to specific questions from the system.

There are standard editing procedures based the service language syntax. They are included as standard subroutines in the program library of the IS-2 interpretive system, which is also used in the AI T-0 system in conjunction with the SIGMA symbolic generator and macro-assembler [47].

The job-scheduling algor..hm dynamically assigns priorities to requests for CPU time based on two criteria: (1) a decrease in the number of swaps between main memory and drum storage; and (2) a decrease in the time service requests spend in the queue for CPU utilization. The system's designers claim a considerable decrease in net response time and in the losses associated with program swapping.

Although this system is very small for time-sharing applications, the possibility of using medium-capability machines for time-sharing is

clearly established--not only from the standpoint of necessary hardware alterations, but also by evidence that time-sharing software of sufficient scope may be developed in Kazan'. The designers point out that debugging and preliminary utilization of the input language and monitor subroutines have shown that the system is easy to operate.

The cost of the additional equipment required for the time-sharing feature is largely limited to the terminals and the interfacing unit. This cost appears to be reasonable. Unfortunately, East German electric typewriter terminals had to be excluded because of the requirement that only domestic, serially produced terminal equipment be used. This probably constrained the scope of software design because of the limited number of keyboard symbols on the RTA-50 telegraph units.

LVOV TELEVISION FACTORY SYSTEM

The importance to Soviet production enterprises of production control, resource-allocation planning, and cost-accounting systems based on computers cannot be overstated. Even when mechanized accounting methods are used, cost-accounting operations in most large enterprises lag actual production by as much as five to ten days [66]. The time-sharing system at the Lvov Television factory, designed to cope with these problems, has received unprecedented press coverage [67-70]. An entire issue of *Mechanization and Automation of Control* was devoted to it [18]. Glushkov, the system's principal designer, was awarded the title "Hero of Socialist Labor"; the Kiev Institute of Cybernetics, which Glushkov heads, received the Order of Lenin Prize. The Lvov system's apparent success is inspiring other major Soviet production enterprises to introduce some of its features into their own production-control systems [71]; Glushkov has indicated his intent to generalize the system for installation elsewhere.

One of the attractions of the Lvov time-sharing system is the use of serially produced Minsk-22 computers augmented by necessary time-sharing equipment expressly designed for this project. Thus, the two Minsk-22 machines (initially one) used as CPUs are equipped with program interrupt, memory protect, and real-time clock units. Additional

hardware provides auxiliary instructions, dynamic analysis of malfunctions, I/O from 30 (expandable to 60) telegraph units, data input from a large number of production and assembly points, computer-generated output displays, and many other interfacing functions.

There are indications that the Lvov time-sharing system operates only with a static number of fixed programs since the program-interrupt unit operates on the principle of fixed priorities. This feature is the only one receiving (somewhat muted) criticism. On the other hand, it may be responsible for the relatively short response time of ~800 msec for any terminal device in the system [72].

Memory protection is carried out in 512-word pages. Any page may be interrogated for the read operation, but intervention of the executive prevents indiscriminate write into protected pages. Address coincidence is used to check whether the appropriate page is freely accessible; this is done by means of indices stored in a special register dividing the entire 8K main memory into 32 equal pages.

The program-interrupt unit, operating in conjunction with the executive, analyzes programs awaiting CPU time in terms of absolute priorities related to the type of input device from which the data and the request for program execution come. The unit also interrupts the current program run if another program with higher priority appears. The machine state corresponding to the interrupted program is stored in the main memory. There appear to be four priority levels, assigned according to the dynamic characteristics of external units, the time necessary to load the appropriate program into the CPU, and the time required for program execution.

The real-time clock synchronizes the solution of control and cost-accounting problems with the flow of production processes. It specifies the current time in days, hours, minutes, and seconds. The CPU uses this information to make periodic program schedules [73].

The Lvov time-sharing software was developed only to a point that would ensure orderly computations associated with production and cost-accounting control. It is not intended for general-purpose programs. Basically, it consists of an executive, represented by 512 instructions, and a monitor, which handles I/O operations [74]. The executive is

responsible for (1) program scheduling according to prespecified priorities, (2) loading of programs and data into the CPU, (3) controlling monitor operation, (4) checking the accuracy of the computation process, and (5) testing for external units, which are automatically disconnected if they malfunction so that production control and accounting are not offset by erroneous data.

The foresight of the Lvov time-sharing designers is exemplified by inclusion of modern data-transmission equipment into the system. This equipment will probably play an important role as a model for such installations in the projected State Network of Computer Centers. The MTS-50, designed at the Institute of Cybernetics, can send or receive 50-75-baud signals in 5-unit telegraph code using a switched telephone network, with error rates much lower than those corresponding to telegraph apparatus used in communications organizations [75]. Another modern feature is a random number generator for modeling production-control processes to facilitate more accurate forecasting of events.

The technical sophistication of this system demonstrates that time-sharing systems can be installed at many Soviet organizations if the development is handled by qualified personnel.

AEROFLOT'S SIRENA-1 SYSTEM

"Sirena-1" is a seat reservation and ticketing time-sharing system designed for the USSR Main Administration of the Civil Air Fleet (Aeroflot) [76-78]. It was scheduled for completion in time for the Five-year Plan deadline, 1970, but is not believed to be fully operational. The system offers either a single fixed application program or a few rigidly delineated application programs.

For our purposes, it is a relatively insignificant development. However, the CPUs used are based on the M-series of computers [79], which are of modular design and have all the requirements for time-sharing operation.

The M-series of computers includes the M-1000, M-2000, and M-3000 (the machine used in Sirena-1), in order of increasing capability. The M-1000 executes 20,000 additions/sec, operating on 16-bit words using

a 1K random-access memory section and 8K, 8-μsec memory for 32-bit words. However, its special-purpose CPU and instruction system (incompatible with the M-2000 and the M-3000) probably preclude its use in time-sharing systems. The M-2000 and M-3000 are able to handle 27,000 opns/sec and 100,000 additions/sec, respectively, using 32-bit words. They have identical random-access memory units characterized by an expandable 8K-word capacity and an 8-μsec cycle time. Both models exhibit identical instruction, program interrupt, and memory-protection systems. In addition, their I/O operations are similarly organized.

Memory protection is handled in 512-word pages. The executive program handles memory protection, as well as simultaneously occurring interrupt signals, according to fixed priority rules.

The Soviets claim that the M-2000 system can be hooked to 256 I/O units and the M-3000 to 320 such devices, but the list of I/O units presented to the State Commission (whose function it is to reject or accept these systems for production) includes no terminal equipment normally associated with time-sharing, except for a telegraph-interface unit. Furthermore, the "Sirena-1" system has only special-purpose terminals, used for data inquiry and automatic typing of purchased airline tickets.

It is too early to tell if the M-series will eventually be used in general-purpose time-sharing since, aside from the seat reservation and ticketing system, no other information is available. However, much emphasis is given to the instruction system, compatible with such machines as the IBM-360 and RCA Spectra-70, and to the modular design, which provides a margin between present system composition and ultimate capability.

VII. CONCLUSIONS

General-purpose time-sharing on some sort of limited basis in the Soviet Union will probably have to await (1) the introduction of more modern computers, with higher operating speeds and greater memory capacities (especially discs); (2) the development, dissemination, and wider application of higher-level languages; and (3) the development of appropriate I/O equipment. This does not mean that some sort of general-purpose time-sharing cannot be implemented in the Soviet Union in the near future; however, its impact would be far less than the increased computer utilization currently being experienced in the United States as a result of time-sharing. This is due to both the limited capabilities of the systems the Soviets could presumably design now and the small number of systems they could produce with current, limited resources. The high cost of such systems also argues against their early appearance.

However, such large modular systems as the Ural and M series and the forthcoming Ryad machines--all of which provide for upward software compatibility--bear watching since they have the potential for implementation in time-sharing systems. In addition, the wider application of existing hardware modified for time-sharing--for example, the Kazan' and Lvov systems--may become trends.

A serious impediment to the full development of time-sharing is unreliable data transmission due to antiquated telephone and telegraph networks. The channels in these networks have large error intensities, with error rates of 10^{-3} for 50-baud channels, as compared to 3×10^{-5} for the less-than-ideal French channels [80]. Until now, this area has received almost no attention. However, as it becomes clear that computer effectiveness, especially in time-sharing applications and in the State Network of Computer Centers, is hindered by the inability to reliably transmit data over even short distances, an increasing number of computer specialists will focus attention on this problem. Glushkov has stated repeatedly that the communications problem is basic to further expansion of computer utilization.

A recurrent theme in the Directives of the 24th Congress of the Communist Party, held in April 1971, is the need to develop a state-wide automated system for collecting and processing information for economic accounting, planning, and management. This system would be based on the State Network of Computer Centers and on a *unified automated network of national communications*. So far, there has been no published report on the details of any of these systems from the viewpoint of the Directives. Nevertheless, the Directives make clear that many, if not all, aspects of improving computer utilization in the Soviet Union are at long last being viewed as a single, interrelated problem that cannot be solved piecemeal. Basic research in time-sharing is unquestionably faltering, but the larger problems of computer technology are finally beginning to receive intense, coordinated attention. A further assessment of time-sharing, or of any major component of Soviet computer technology, awaits the introduction of the Ryad computers (within the next year, according to schedules) and an examination of their potential.

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An account of a trip taken by two RAND computer specialists to the Soviet Union as part of an eight-man delegation representing the U.S. National Joint Computer Committee and its member societies. The genesis of the delegation and its itinerary in the Soviet Union are traced. The state of the art in Soviet computer technology as observed by the delegates is examined, showing the development, constructions, applications, routines, and components of the major Soviet computing machines. Impressions are included on Soviet education, the role of the Academy of Sciences, and Chinese developments in computer technology. Many photographs of Soviet machines, components, people, and places are included. First-hand information is also given on the BESM-I, BESM-II, Strela, Ural, and Kiev computers, plus several other machines. Machine specifications are presented in chart form, facilitating comparisons; op codes are given for the Ural-1 and Ural-2. 205 pp. Illus.

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have been indexed. Russian-English and English-Russian glossaries of all ALGOL and ALGEC terms are appended. (The version of ALGEC translated in this Memorandum is superseded by that contained in Part VIII, RM-5136-PR.) 158 pp.

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A translation of the final version of the new Soviet Algorithmic Language for Economics Problems (ALGEC), a general-purpose computer programming language that can use both Latin and Cyrillic alphabets and either Russian or English reserved words. Based on ALGOL 60 and SUBSET ALGOL 60, ALGEC has been modified to permit the handling of tables, records, indexes, etc., and documents of complex format and variable length; it also provides a means of selecting and processing individual items from such documents and from non-numerical textual matter. Ideas and input-output procedures were taken from COBOL-61. The Memorandum includes a translation of M. Korolev's article on the development of ALGEC, a brief biographical note on the Russian authors and editor, a Russian-English glossary of ALGEC terminology, and an English-Russian glossary included in an index to definitions of terms and syntactic units. 152 pp.

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A summary and evaluation of the preliminary and final versions of ALGEC, the Soviets' Algorithmic Language for Economics Problems. The ALGEC computer programming language for economics data processing is an almost pure extension of ALGOL 60. The deletions are in conformity with the IFIP-approved SUBSET ALGOL. The extensions add features obviously needed to handle non-numeric data. While not a complete list-processing language, ALGEC

appears to be adequate for business data processing, with the possible exception of decimal arithmetic. Also, input-output transfers cannot be identified by source. The retention of nested strings from ALGOL is an unnecessary complication, and the use of COBOL-style data structures (lists) precludes the handling of data with complex and dynamically varying relationships. Definitions lack precision, and the semantic and syntactic rules are unrealistic, 51 pp.

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An unannotated translation of a Soviet review of the collection of articles, Computers and Thought, edited by E. A. Feigenbaum and J. Feldman. The review was published in a Soviet journal that specializes in reviewing books published in the West. The reviewers briefly cover each section of the collection, paying special attention to many of the individual articles. Some clues to Soviet attitudes

can be obtained from the reviewers' comments. The treatment is quite favorable, and the review closes with a recommendation that the entire collection be translated into Russian. [A Russian edition was published in 1967, <u>Vychislitel'nye mashiny i myshlenie</u>, Izdatel'stvo "Mir," Moscow.]

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A critical survey of Soviet efforts to develop a mathematical theory of computer programming and automatic programming methods. The study traces the development of the 'operator' theory of A. A. Lyapunov and his associates from its starting point in program schemes designed to represent specific problem-solving algorithms to its algebraic formulation in terms of the theory of categories. Other authors have attempted to adapt graph theory and the theory of algorithms to the construction of better programming languages. In contrast to FORTRAN, the practical result of programming programs has been to raise, rather than lower, the level of technical knowledge required for programming. Current Soviet research is directed toward adaptation and extension of ALGOL-60 rather than further theoretical work. Some of the Soviet work, however, may be of practical relevance, particularly Glebov's synthesis of operators from measurably simpler ones. 144 p. Refs.

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A listing, by author, of all the publications of Soviet origin, or published in the Soviet Union, that were abstracted in the 1964 issues of the <u>Referativnyj zhurnal--Kibernetika</u>, a monthly publication of the All-Union Institute of Scientific and Technical Information under the USSR Academy of Sciences. The listing contains the bibliographic data only, not the abstracts. The coverage reflects the extremely broad meaning of "cybernetics" in the Soviet Union: it is applied to mathematical and computational techniques and to all forms of information, communication, and control, including, for example, such areas as programmed instruction and

neurophysiology. Works in seven Soviet languages are included. All entries have been translated into English. A complete citation is given under each author of a joint work. A list of 55 Soviet publishing houses and 185 titles of journals and irregular serial publications, as extracted from the citations, is included. 303 pp.

18. Barsamian, Harut, Soviet Cybernetics Technology: XI. Homogeneous, General-Purpose, High-Productivity Computer Systems--A Review, RM-5551-PR, April 1968.

A review and evaluation of the first Soviet book entirely devoted to problems of high-productivity computing systems. Published in late 1966, the book reports on studies conducted at the Institute of Mathematics in Novosibirsk. Since the Soviet system of national economic planning requires a large volume of coordinated, relatively simple calculations, and Soviet computer technology does not equal that of the West, the authors, E. V. Evreinov and Yu. G. Kosarev, have sought a way to increase computer productivity without greatly increasing technological demands. Their solution is parallelism [illegible] coupling of up to 1000 [illegible]ters, each capable of a million operations per second, so that all work together on the same program at the same time. However, the authors have not succeeded in establishing a new approach based on parallelism that will solve the problem of increased productivity, nor have they made a convincing case for their basic assumptions. The proposed linking of 1000 branch computers to achieve the desired throughput is not feasible, nor is the use of homogeneous computing media to develop the microstructure of the system. Methods of controlling and monitoring parallel algorithms are not considered. Although all theoretical conclusions were supposedly verified on the experimental Minsk-222 system (consisting of Minsk-[illegible] and Minsk-22 computers), the actual results are not documented and there is no clear description of the operations performed. 33 pp.